Our Motivation:

to work for a better future

Climate change is one of the greatest challenges of our time. In order to still reach the 1.5° target, all scientists must join forces and ask themselves how they can make a contribution with their research.

That is exactly what we have done. In order to slow down climate change, carbon capturing and storage methods will gain in importance in the future. CCS refers to the storage of CO2 in the seabed so that it does not reach the atmosphere. Renewable energies also require large quantities of rare metals. To meet this demand, deep-sea mining, the extraction of these metals from the seabed, has recently become a topic of discussion.

In order to realise these projects, meaningful models of the seabed are important, but subsurface modelling is an NP hard problem. Quantum computers could help to improve these calculations, as classical computers have reached their limits with the simulations.

State of the art

- subsurface imagining is an NP hard problem

- current methods to solve it:
  - Nature inspired global solvers [Pierini et al., 2019]
    - Firefly Algorithm
    - Whale Swarm Optimisation
  - Simulated Annealing [Rothman, 1985]

- methods in research
  - Quantum Annealing

What we do

We want to implement an equivalent **gate-based solution in Qiskit**. Using as a basis the research, which has be done on solving this problem by using Quantum Annealing.

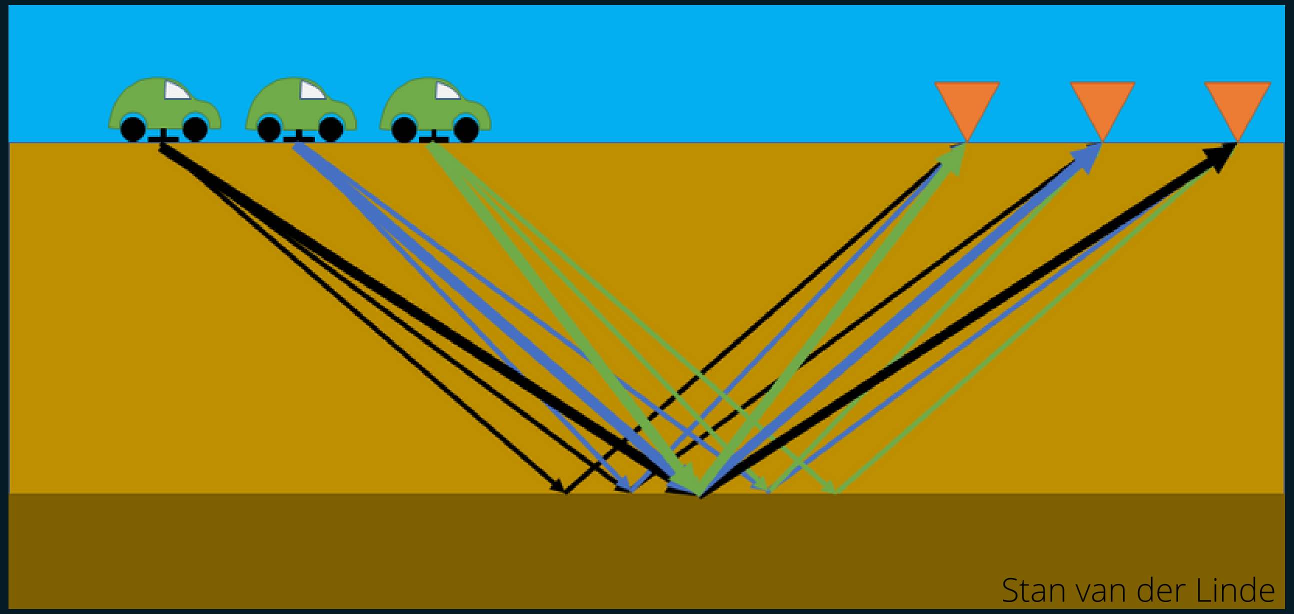
Why Quantum Computing?

For seismic experiments multi-path analysis is required. The problem size is given by:

Traces^(possible shifts) -> NP hard problem

A Quantum Image ideally covers all paths, which gives a more precise solution.

At the moment gate-based quantum computers are composed of O(10) bits while quantum annealers have O(10^3) bits, but there is a fast progress with quantum computing hardware. But a universal quantum computer can be used for more problems than a quantum annealer. That is why one could assume that in the future the market will focus on these machines and then gate-based algorithms are needed. Moreover, are gate-based computers easier to handle for non-experts, so that geoscientists could use them without the help.

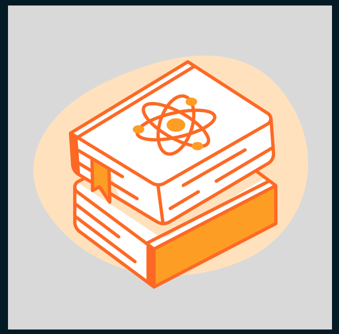


What we have done

We were able to implement the code, which is used in Quantum Annealing, on Qiskit.

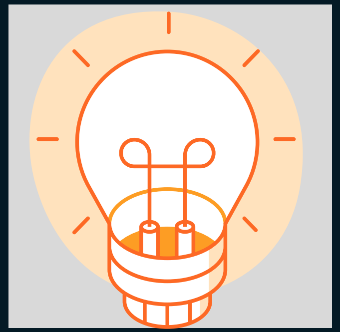
Looking into existing algorithms

We compared existing algorithms and their weaknesses. We focused on the paper "An approach to quantum-computational hydrologic inverse analysis" by Daniel O'Malley. Your original goal was to implement a gate-based solution similar to the paper in Qiskit.



Research

We realized that there already exist a Quadratic Optimization function in Qiskit, which we can use. Since there is no need to reinvent the wheel, we decided to use it.



Qiskit Implementation

We implemented the three examples from the paper in Qiskit: the small 1D problem, a large 1D problem and a 2D problem.

Next Steps

The existing code is a good starting point and lays the foundation for further development of the project. Nevertheless, the success of the project depends to a large extent on the further development of quantum computers. This page outlines your strategy for continuing the good work done so far.

Test on real data

In a next step our program should be tested on real geophysical data. The model achieved with our code must be compared to classical models and models achieved by Quantum Annealing.

Iterative circle

By comparing our results with the reality and other models, we can find things which should be improved. After improving, we need to test again and again.

Waiting for Quantum Computers to scale

To perform better than the existing solutions it is necessary, that quantum computer will scale up. But once this happens, we are ready to revolutionize subsurface-imaging.